# Matteo Croci | Curriculum Vitae

Ikerbasque, the Basque Foundation for Science & Basque Center for Applied Mathematics (BCAM)
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Research Interests

My research has always been interdisciplinary, working at the interface between different fields in applied mathematics and computational engineering. I work in the fields of computational stochastics, uncertainty quantification and computational and industrial mathematics, with a focus on multilevel (quasi) Monte Carlo methods and biomedical computing. More recently, I have become an expert in reduced- and mixed-precision computing, in particular in the development of reduced- and mixed-precision methods for the numerical solution of differential equations.

My research interests are:

- Multilevel (quasi) Monte Carlo methods.
- Reduced- and mixed-precision numerical algorithms.
- Uncertainty quantification.
- Fast Gaussian field sampling and PDEs with random coefficients.
- Mathematical modelling of the physiology of the brain.
- Finite element method.
- Multiple solutions of variational inequalities.
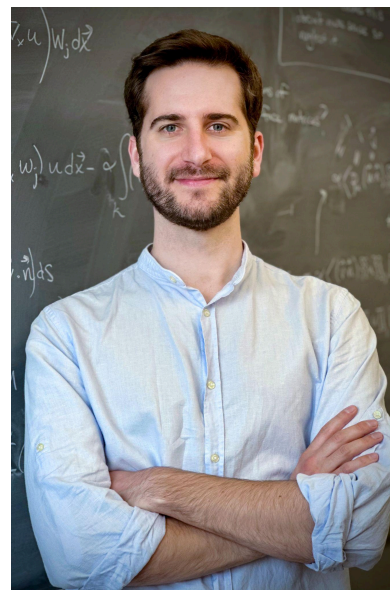
Current and Previous Research Positions

2024–pres. **Ikerbasque and Ramón y Cajal Research Fellow**. Ikerbasque, the Basque Foundation for Science and BCAM, the Basque Center for Applied Mathematics, Bilbao, Spain.

2024. **Marie Skłodowska-Curie Fellow**. Basque Center for Applied Mathematics, Bilbao, Spain.

2022–2024. **Research Associate** (research fellow). Oden Institute for Computational Engineering and Sciences (OICES), University of Texas at Austin, Austin, TX, USA.

2021–2022. **Postdoctoral fellow**. Oden Institute for Computational Engineering and Sciences (OICES), University of Texas at Austin, Austin, TX, USA. Group Leaders: R. D. Moser and K. E. Willcox.

2020–2021. **Postdoctoral fellow**. Mathematical Institute, University of Oxford, UK. Group Leader: M. B. Giles.

2016–2020. **Visiting PhD researcher**. Simula Research Laboratory, Norway. Group Leader: M. E. Rognes.

Education

2015–2020. **DPhil (PhD) in Mathematics**. University of Oxford, UK.
Thesis title: "Multilevel Monte Carlo Methods for Uncertainty Quantification in Brain Simulations".
Supervisors: P. E. Farrell, M. B. Giles.
Industrial advisor: M. E. Rognes.

2014–2015. **MSc in Mathematical Modelling and Scientific Computing**. University of Oxford, UK.
Thesis title: "Deflation Methods for Complementarity Problems". Supervisor: P. E. Farrell.
Final award: distinction (highest possible).

2011–2014. **BSc in Mathematical Engineering**. Politecnico di Milano, Milan, Italy.
Final award: 110/110 cum laude (highest possible distinction).

2013. **Exchange Student in Mathematics and Engineering**. University of Maryland, College Park, MD, USA. <u>Award:</u> academic honors (highest possible distinction).

Grants & Awards

2023. **Spanish State Research Agency: Ramon y Cajal Research Fellowship and Grant.**

2023. **Basque Foundation for Science: Ikerbasque Research Fellowship.**

2023. **Horizon Europe: Marie Skłodowska-Curie Fellowship.** <u>Ranking in the top 1% of applicants with a score of 98.8% and a perfect score in the "Excellence" section.</u>

2023. **Leslie fox Prize in Numerical Analysis**, second place, for the development of mixed-precision explicit Runge-Kutta methods.

2023. **SIAM ICIAM 2023 Travel Award.** Society for Industrial and Applied Mathematics. Prize amount: 1750$.

2020. **Charles Broyden Prize.** Best paper published in Optimization methods and software in 2020.

2015–2019. **Oxford-Radcliffe Scholarship.** University of Oxford, University College, Oxford, UK.

2013. **Academic honors for the Fall Term**. University of Maryland, College Park, MD, USA.

2011–2013. **Scholarship for students with very high merit**. Politecnico di Milano, Milan, Italy.

2011–2012. **Award for best freshmen in the academic year**. Politecnico di Milano, Milan, Italy

Publications

[1] <u>M. Croci</u>, K. E. Willcox, S. J. Wright. *Multi-output multilevel best linear unbiased estimators via semidefinite programming*. Computer Methods in Applied Mechanics and Engineering (2023). (**Quartile: Q1. Impact factor: 5.763**). DOI: https://doi.org/10.1016/j.cma.2023.116130. Open-access preprint: https://arxiv.org/abs/2301.07831.

[2] <u>M. Croci</u>, J. Muñoz-Matute. *Exploiting Kronecker structure in exponential integrators: fast approximation of the action of φ-functions of matrices via quadrature*. Journal of Computational Science (2023). (**Quartile: Q1. Impact factor: 3.976**). DOI: https://doi.org/10.1016/j.jocs.2023.101966. Open-access preprint: https://arxiv.org/abs/2211.00696.

[3] <u>M. Croci</u>, G. Rosilho de Souza. *Mixed-precision explicit stabilized Runge-Kutta methods for single-and multi-scale differential equations*. Journal of Computational Physics (2022). (**Quartile: Q1. Impact factor: 4.645**). DOI: https://doi.org/10.1016/j.jcp.2022.111349. Open-access preprint: https://arxiv.org/abs/2109.12153.

[4] <u>M. Croci</u>, M. B. Giles. *Effects of round-to-nearest and stochastic rounding in the numerical solution of the heat equation in low precision*. IMA Journal of Numerical Analysis (2022). (**Quartile: Q1. Impact factor: 2.713**). DOI: https://doi.org/10.1093/imanum/drac012. Open-access preprint: https://arxiv.org/abs/2010.16225.

[5] <u>M. Croci</u>, M. Fasi, N. J. Higham, T. Mary, M. Mikaitis. *Stochastic rounding: implementation, error analysis, and applications*. Royal Society Open Science (2022). (**Quartile: Q1. Impact factor: 3.653**). Open-access DOI: https://doi.org/10.1098/rsos.211631.

[6] J. Enderlein, D. Sakhapov, I. Gregor, <u>M. Croci</u>, N. Karedla. *Modeling charge separation in charged nanochannels for single-molecule electrometry*. Journal of Chemical Physics (2022). (**Quartile: Q1. Impact factor: 4.304**). DOI: https://doi.org/10.1063/5.0074732. Open-access preprint: https://zenodo.org/record/6983885.

[7] M. Klöwer, S. Hatfield, <u>M. Croci</u>, P. Düben, T. Palmer. *Fluid simulations accelerated with 16 bit: Approaching 4x speedup on A64FX by squeezing ShallowWaters.jl into Float16*. Journal of Advances in Modeling Earth Systems (2021). (**Quartile: Q1. Impact factor: 8.47**). Open-access DOI: https://doi.org/10.1029/2021MS002684.

[8] <u>M. Croci</u>, M. B. Giles, P. E. Farrell. *Multilevel quasi Monte Carlo methods for elliptic PDEs with random field coefficients via fast white noise sampling*. SIAM Journal on Scientific Computing (2021). (**Quartile: Q1. Impact factor: 2.373**). DOI: https://doi.org/10.1137/20M1329044. Open-access preprint: https://arxiv.org/abs/1911.12099.

[9] <u>M. Croci</u>, V. Vinje and M. E. Rognes. *Fast uncertainty quantification of tracer distribution in the brain interstitial fluid with multilevel and quasi Monte Carlo*. International Journal for Numerical Methods in Biomedical Engineering (2020). (**Quartile: Q1. Impact factor: 2.648**). Open-access DOI: https://doi.org/10.1002/cnm.3412.

[10] <u>M. Croci</u>, P. E. Farrell. *Complexity bounds on supermesh construction for quasi-uniform meshes*. Journal of Computational Physics (2020). (**Quartile: Q1. Impact factor: 4.645**). DOI: https://doi.org/10.1016/j.jcp.2020.109459. Open-access preprint: https://arxiv.org/abs/1911.11589.

[11] P. E. Farrell, <u>M. Croci</u>, T. M. Surowiec. *Deflation for semismooth equations*. Optimization Methods and Software (2020). **2020 Charles Broyden prize**. (**Quartile: Q1**. **Impact factor: 1.832**). Open-access DOI: https://doi.org/10.1080/10556788.2019.1613655.

[12] <u>M. Croci</u>, V. Vinje, M. E. Rognes. *Uncertainty quantification of parenchymal tracer distribution using random diffusion and convective velocity fields*. Fluids and Barriers of the CNS (2019). (**Quartile: Q1**. **Impact factor: 6.961**). Open-access DOI: https://doi.org/10.1186/s12987-019-0152-7.

[13] <u>M. Croci</u>, M. B. Giles, M. E. Rognes, P. E. Farrell. *Efficient white noise sampling and coupling for multilevel Monte Carlo with non-nested meshes*. SIAM/ASA Journal on Uncertainty Quantification (2018). (**Quartile: Q1**. **Impact factor: 2.041**). DOI: https://doi.org/10.1137/18M1175239. Open-access preprint: https://arxiv.org/abs/1803.04857.

Research stays

2022 (3 days). Sandia National Laboratories (USA). Visiting T. Wildey, M. Eldred, G. Geraci.

2022 (3 days). Northwestern University (USA). Visiting J. Nocedal (highly cited researcher).

2022 (3 days). University of Minnesota - Twin Cities (USA). Visiting G. Lerman, Y. Saad (highly cited researcher), L. Shen (highly cited researcher), L. Wang, A. Ebtehaj.

2016–2020 (6 months across this period). Simula Research Laboratory (Norway). Working with M. E. Rognes.

2019 (2 months). University College London (UK). Visiting John C. Vardakis and Vegard Vinje.

2015 (3 months). Nielsen (UK). Research collaboration with Gisella Mercaldi, Ludo Daemen (Nielsen, UK).

Conference presentations

[C1] <u>M. Croci</u>, K. E. Willcox, S. J. Wright. *Multi-output multilevel BLUEs via semidefinite programming*. **ICIAM 2024**, Tokyo, Japan. August 20-25, 2023.

[C2] <u>M. Croci</u>, K. E. Willcox, S. J. Wright. *Multi-output multilevel BLUEs via semidefinite programming*. **USNCCM 17**, Albuquerque, NM, USA. July 23-27, 2023.

[C3] <u>M. Croci</u>, G. Rosilho De Souza. *Order-preserving mixed-precision RK methods*. **FEniCS 2022**, La Jolla, CA, USA. August 22-24, 2022.

[C4] <u>M. Croci</u>, M. B. Giles. *Stochastic rounding for parabolic PDEs in half precision*. **SIAM CSE 2021**, virtual conference. March 1-5, 2021.

[C5] <u>M. Croci</u>, M. B. Giles, M. E. Rognes, P. E. Farrell. *MLQMC methods for elliptic PDEs driven by white noise*. **ICIAM 2019**, Valencia, Spain. July 15-March 19, 2019.

[C6] <u>M. Croci</u>, M. B. Giles, M. E. Rognes, P. E. Farrell. *MLQMC methods for elliptic PDEs driven by white noise*. **SIAM CSE 2019**, Spokane, WA, USA. February 25-March 1, 2019.

[C7] <u>M. Croci</u>, M. B. Giles, M. E. Rognes, P. E. Farrell. *Efficient white noise sampling and coupling for multilevel Monte Carlo*. **13th MCQMC**, Rennes, France. July 1-6, 2018.

[C8] <u>M. Croci</u>, M. B. Giles, M. E. Rognes, P. E. Farrell. *White noise coupling for multilevel Monte Carlo*. **SCICADE 2017**, Bath, UK. September 11-15, 2017.

Talks and participation at study groups with industry

[SG1] <u>M. Croci</u>, S. G. Marquis. *Tackling the ExploreSA challenge via machine-learning anomaly detection*. Industrial partner: Unearthed (Australia). **MISG 2019**, Adelaide, Australia. January 21-25, 2019.

[SG2] C. Beentjes, D. Chainikov, <u>M. Croci</u>, J. van der Gaast, S. Kapodistria, S. Rahimi-Ghahroodi, F. Sloothaak, F. Spieksma. *Optimal order picking from a large retailer warehouse*. Industrial partner: CQM (Netherlands). **ESGI 135-SWI 2018**, Eindhoven, Netherlands. January 29-February 2, 2018. Contribution: optimisation and stochastic modelling research lead.

[SG3] M. Croci, P. Morawiecki, J. Prater, V. Sulzer, F. Theil. *Classification of Two-Dimensional Gas Chromatography Data.* Industrial partner: DSTL (UK). **ESGI 130**, Warwick, UK. September 4-8, 2017.

Invited Seminar presentations

[IS1] M. Croci, *Multi-output multilevel BLUEs via semidefinite programming.* **Sandia National Laboratories**, NM, USA. October 14, 2022.

[IS2] M. Croci, *A review of mixed-precision methods in scientific computing.* Center for Optimization and Statistical Learning seminar. **Northwestern University**, IL, USA. October 6, 2022.

[IS3] M. Croci, *Multi-output multilevel BLUEs via semidefinite programming.* IMA Data Science seminar. **Institute for Mathematics and its Applications - University of Minnesota**, MN, USA. September 20, 2022.

[IS4] M. Croci, *Solving differential equations in reduced and mixed precision.* Applied Computational Maths seminar. **University of Minnesota**, MN, USA. September 19, 2022.

[IS5] M. Croci, *Mixed-precision order-preserving Runge-Kutta methods.* **Exascale computing project - Multiprecision Effort Team** seminar (online). May 26, 2022.

[IS6] M. Croci, *Solving differential equations in reduced and mixed precision.* Applied Mathematics seminar. **University of Yale**, CT, USA. March 9, 2022.

[IS7] M. Croci, *Solving differential equations in reduced and mixed precision.* MATHICSE seminar. **École polytechnique Fédérale de Lausanne (EPFL)**, Switzerland. February 2, 2022.

[IS8] M. Croci, M. B. Giles, *Solving parabolic PDEs in half precision.* Applied Mathematics seminar, **University of Leicester**, UK. March 25, 2021.

[IS9] M. Croci, M. B. Giles, *Solving parabolic PDEs in half precision.* PEQUAN seminar, **Computer Science Laboratory LIP6 - Sorbonne Université**. February 24, 2021.

[IS10] M. Croci, M. B. Giles, P. E. Farrell, M. E. Rognes, V. Vinje, *Non-nested multilevel Monte Carlo methods for PDEs with random coefficients.* **Courant Institute of Mathematical Sciences, New York University (NYU)**, NY, USA. February 18, 2021.

[IS11] M. Croci, M. B. Giles, P. E. Farrell, V. Vinje, M. E. Rognes, *Non-nested multilevel Monte Carlo methods with applications to brain simulation.* Oden Institute Seminar, **University of Texas at Austin**, TX, USA. February 10, 2021.

[IS12] M. Croci, M. B. Giles, *Solving (parabolic) PDEs in half precision.* Predictability of weather and climate group seminar, **Physics Department - University of Oxford**, UK. January 18, 2021.

[IS13] M. Croci, M. B. Giles, *Solving parabolic PDEs in half precision.* Numerical linear algebra seminar, **University of Manchester**, UK. December 7, 2020.

[IS14] M. Croci, M. B. Giles, *Solving parabolic PDEs in half precision.* SCAN department seminar, **Simula Research Laboratory**, Norway. December 2, 2020.

Organised conferences and seminars

2020–2021. **Organiser of the North Meet South colloquia.** University of Oxford, UK.

2019–2021. **Organiser of the Stochastic Simulation seminars.** University of Oxford, UK.

2018. **Organiser of the FEniCS'18 international conference.** University of Oxford, UK.

Supervision and mentoring

2021. **Supervision of MSc student** M. Robertson of the MSc in Mathematical Modelling and Scientific Computing of the University of Oxford, UK. Dissertation title: *Mixed-Precision Strong Stability Preserving Runge-Kutta Methods for Hyperbolic Conservation Laws.* Final outcome: distinction (highest possible grade).

2018-2021. **Numerical Analysis Group graduate student coordinator.** Acted as lead mentor to guide and assist all PhD students ($\cong$20 at the time) in the Numerical Analysis group.

2016-2020. Mentoring PhD students F. Danieli, K. Kiradjiev, and MSc student P. Canipet. Mathematical Institute, University of Oxford, UK.

Research Projects

[RP1] **Spanish State Research Agency: Ramón y Cajal Fellowship.** Coordinator: **M. Croci**. 01/09/2024-31/08/2029. Budget: 314,350€. Role: **principal investigator**.

[RP2] **Basque Foundation for Science: Ikerbasque Fellowship.** Coordinator: **M. Croci**. 01/02/2024-31/01/2029. Budget: 10,000€. Role: **principal investigator**.

[RP3] **Horizon Europe, Marie Skłodowska-Curie Fellowship**. "GEOLEARN: Real-time hydrogen-storage monitoring via energy-efficient deep learning". Coordinator: **M. Croci**. Grant number: 101103593. Budget: 181,152.96€. Role: **principal investigator**.

[RP4] **US Department of Energy**, **PSAAP III program**. "Exascale Predictive Simulation of Inductively Coupled Plasma Torches". Coordinator: R. D. Moser. Grant number: DE-NA0003969. 30/09/2020-29/09/2025. Budget: 19,200,000$. Role: **leading research in multilevel/multifidelity Monte Carlo methods**.

[RP5] **UK Engineering and Physical Sciences Research Council programme (EPSRC)**. "PRISM: Platform for Research In Simulation Methods". Coordinators: S. J. Sherwin and others. Grant number: EP/R029423/1. 01/07/2018 - 31/12/2023. Budget: 1,612,965£. Role: research team member.

[RP6] **US Department of Energy**. "Partnership Center for High-Fidelity Boundary Plasma Simulation". Coordinator: R. D. Moser. Grant number: DE-SC0018148. 01/09/2017 - 31/08/2023. Budget: 915,000$. Role: **leading research in multilevel/multifidelity Monte Carlo methods**.

[RP7] **UK Engineering and Physical Sciences Research Council programme (EPSRC). "**Inference, COmputation and Numerics for Insights into Cities (ICONIC)". Coordinators: M. Girolami, N. J. Higham, M. B. Giles, D. J. Higham. Grant number: EP/P020720/1. 01/06/2017 - 18/03/2019. Budget: 2,964,066£. Role: **leading research in RP/MP methods for PDEs**.

[RP8] **EU Horizon 2020 research and innovation programme.** "Mathematical and computational foundations for modeling cerebral fluid flow (WATERSCALES)". Coordinator: M. E. Rognes. Grant number: 714892. 01/04/2017 - 31/03/2023. Budget: 1,500,000€. Role: **work package leader**.

[RP9] **Research Council of Norway**, "The Numerical Waterscape of the Brain". Coordinator: M. E. Rognes. Grant number: #250731. 01/04/2016 - 31/05/2020. Budget: 7,000,000 NOK. Role: **work package leader**.

[RP10] **Nordic Council of Ministers via NordForsk**. "Automated uncertainty quantification for numerical solutions of partial differential equations". Coordinators: J. Sundnes, M. E. Rognes. Grant number: #74756. 01/04/2015 - 31/03/2018. Budget: 7,300,000 NOK. Role: research team member.

[RP11] **UK Engineering and Physical Sciences Research Council programme (EPSRC).** "A new simulation and optimisation platform for marine technology". Coordinator: P. E. Farrell. Grant number: EP/M011151/1. 01/01/2015 - 31/12/2017. Budget: 76,550£. Role: research team member.

[RP12] **UK Engineering and Physical Sciences Research Council programme (EPSRC).** "Automating optimisation subject to partial differential equations on high-performance computers". Coordinator: P. E. Farrell. Grant number: EP/K030930/1. 01/10/2013 - 30/09/2018. Budget: 487,241£. Role: research team member.

Collaboration Contracts with Companies

[CC1] **M. Croci**, J. Tanner, L. Daemen, G. Mercaldi, A. Ottavi. "Matrix completion generalization to tensor completion and multi-way tables". *Nielsen,* US, 2016. Budget: 5,000£. Result: 1 internal technical report and 1 public lay report (bit.ly/3CJqiQj).

[CC2] **M. Croci**, P. E. Farrell, M. B. Giles, M. E. Rognes. "Uncertainty Quantification through multilevel Monte Carlo simulation in FEniCS". *Simula Research Laboratory*, Norway, 2016-2020. Budget: 29,000£. Result: 3 academic papers.

Administrative Duties

2020–2021. **Early Career Researchers Committee member.** Mathematical Institute, University of Oxford, UK.

2020–2021. **Health and Safety Committee member.** Mathematical Institute, University of Oxford, UK.

Peer-review

Acted as a reviewer for a total of **9 journals**, including the following **Q1 journals**: Mathematical Programming, SIAM Journal on Scientific Computing, Journal of Computational Physics, SIAM Journal on Mathematics of Data Science, SIAM/ASA Journal on Uncertainty Quantification, and the Quarterly Journal of the Royal Meteorological Society.

Selected Teaching Experience (all at the University of Oxford, UK)

2020–2021. **Lecturer.** Course: *Matlab Programming*. Degree: MSc in Mathematical Modelling and Scientific Computing.

2019–2021. **Tutor.** Course: *Stochastic Simulation*. Degree: Mathematics of Random Systems CDT (PhD course)**.**

2018–2019. **Head demonstrator.** Course: *Computational Mathematics*. Degrees: all BSc degrees in Mathematics. Duties: Coordinating all demonstrators (tutors) and all ($\cong$200) first year students, and organising all classes.

2017–2019. **Tutor.** Course: *Advanced Monte Carlo Methods*. Degree: MSc in Mathematical and Computational Finance.

2016–2018. **Tutor.** Courses: *Continuous Mathematics, Computational Mathematics, and Numerical Solutions of Differential Equations II.* Degrees: all BSc degrees in Mathematics.

2016–2017. **TA.** Courses: *Numerical Analysis and Numerical Solutions of Differential Equations II.* Degrees: all BSc degrees in Mathematics.

Industrial and public outreach and dissemination activities

2017-2020. Presented current research at the InFoMM Annual Meeting at St. Catherine's College (University of Oxford, UK) in front of representatives from over 20 companies, including: Arm, BP, BT, CCFE, Arup, AtdBio, Bbox, DSTL, Schlumberger, JDE, NPL, Tesco, Sharp, Siemens, Elkem, and others.

2019. Gave a tutorial on advanced Monte Carlo methods and computational stochastics to end users in the finance industry at the University of Oxford, UK.

2018. Helped the organisation of the "*It All Adds Up*" outreach event at the Mathematical Institute in Oxford whose aim is to inspire young women in year 9-12 to continue with Maths education.

2018. Collaborated with the Oxford Mathematical Institute communication staff and published a short article on the institute website to disseminate current research ideas to the general public (www.maths.ox.ac.uk/node/30078).

2017. Organised a day of outreach lectures aimed at disseminating Maths research ideas to the high school pupils of St Gregory the Great School in Oxford, UK.

2015-2016. Visited five companies (McLaren, Sharp, JDE, Dunhumby, Siemens) to promote research collaborations between industry and the Mathematical Institute of the University of Oxford (UK).

Languages

Italian: native language, **English**: fluent, **Spanish**: fluent, **French**: basic.

Programming Languages & Software

Programming Languages: Python, C++, C, Fortran, Bash, MATLAB, R.

Software: MPI, OpenMP, CUDA, FEniCS, PETSc, Pybind11, TensorFlow/Keras, scikit-learn, Intel MKL library, KNITRO, SAS, Git, LATEX, Gurobi, slurm, MS Office.